ERS–535

AQUA AMMONIA'S ECONOMIC POTENTIAL As a Preservative for Stored High-Moisture Corn

U.S. DEPARTMENT OF AGRICULTURE • ECONOMIC RESEARCH SERVICE

ABSTRACT

Potential demand for treatment of cnfarm stored corn is sufficient to justify a profitable local supply of aqua ammonia by farm supply firms that operate convertor units. A 500-ton (considered a minimum) seasonal output would necessitate about a $30 per ton supply price delivered at the farm. The supply price could decrease to about $22 per ton at a 4,000-ton output (maximum for small convertor plants). Aqua ammonia treatment costs would amount to only about one-third the usual drying costs and one-fourth to one-fifth the cost of treatment with organic chemicals. Additional potential advantages include: (1) less care and movement of stored grain, (2) added nonprotein nitrogen to stored grain, and (3) savings of the critically short gas energy used for drying.

Keywords: Corn, Spoilage, Aqua ammonia, Supply and demand, Storage, Treatment, Preservation, Cost estimates, Drying, Moisture, and Savings.

Washington, D.C. 20250 October 1973

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SUMMARY

An annual savings of $150-$175 million could result from treating corn stored on farms with aqua ammonia. Should aqua ammonia treatment of high-moisture corn prove technically effective and feasible, farmers could save 5 cents per bushel on preservation measures.

Aqua ammonia treatment would amount to only about one-third the cost of artificial drying--the preservation method most widely used--and one-fourth to one-fifth the cost of organic chemical treatments. In addition, use of aqua ammonia could lessen the need for artificial drying and substantially reduce the power needed to run the dryers.

Farmers would apply aqua ammonia with a metered applicator, similar to the type used in applying propionic acid, attached to a conveyor that moves corn into a farm storage unit. One ton of aqua ammonia would treat about 1,700 bushels, or 20 acres of corn yielding 85 bushels per acre.

Before aqua ammonia can be used as a corn preservative, more knowledge must be gained concerning the chemical reaction of ammonia with corn constituents. Quantification of caloric loss during heating, modification of amino acids in grain and their effect in feeding, rates of fixation and storage life, and odor and color problems are only a few areas that need laboratory attention.

To obtain a supply of aqua ammonia, anhydrous ammonia must be converted into the liquid form. Long-distance transportation of aqua ammonia from central or regional supply points is considered economically unfeasible. Therefore, local convertor units would need to supply the local area.

Since aqua ammonia has been in use as a fertilizer, many convertor units already exist throughout the Corn Belt States. For instance, in Illinois, over 100 convertor units--some idle and some still in use--are owned by local farm-supply firms. With the decline in use of aqua ammonia as a fertilizer (in favor of the anhydrous form), many of the convertors could serve as available capital equipment for production of aqua ammonia as a preservative.

The smallest commercial unit for converting anhydrous ammonia to aqua ammonia could probably produce up to 4,000 tons (assumed maximum) of aqua ammonia per season. Including equipment for production, storage, handling, and farm delivery, the current investment cost would amount to about $38,000. Overhead costs would be about 32 percent of total cost per ton at a 500-ton seasonal output (assumed minimum volume for profitable operation) and would lower to about 6 percent of total costs at a 4,000-ton output. The total supply cost--including overhead, plant operation, a built-in profit factor, and farm delivery of the product--would amount to about $30 per ton at the 500-ton (minimum) volume and $22 per ton at the 4,000-ton (maximum) volume. The costs for operation of larger plants were not studied. Should local demand be sufficient to justify their purchase, costs per unit supplied would almost surely be less than those of the small units.

Advantages aqua ammonia may have, other than costs, include: (1) less care and movement of grain in storage, (2) added nitrogen in the feed, and (3) potential savings of the critically short gas energy supply. These and other potential benefits of aqua ammonia treatment were not included in cost estimates in the study.

AQUA AMMONIA'S ECONOMIC POTENTIAL AS A PRESERVATIVE FOR STORED HIGH-MOISTURE CORN

By

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INTRODUCTION

Measures to preserve grain in storage have become increasingly important since World War II, because of changing technology, commercialization, and specialization in farming. Harvesting with mechanical equipment, particularly the recent widespread and rapid adoption of the picker-sheller and combine with a corn head, has tended to add to the problem of preserving stored corn. More than three-fourths of the corn in the Corn Belt is now harvested by combine or picker-sheller, compared with less than 20 percent harvested this way in the early 1960's (table 1). With the increasing use of mechanical equipment, higher moisture corn is now being harvested, more shelled and less ear corn is going into storage, and a greater proportion of the corn harvested is moving into market channels. Therefore, the need for measures to preserve the quality of corn while in storage has intensified.

Stored Corn Spoilage

Shelled corn with 13-percent moisture content or less is safe for storage if adequate care is taken to avoid the development of "hot spots." At higher levels of moisture content, the corn is subject to mold growth and spoilage and possible formation of mycotoxin. An annual average of 250 million bushels of corn is estimated to be lost in the United States from mold spoilage (5). 2/

The extent of animal loss from eating grain containing mycotoxin is not known, but indications are that the loss is substantial. Isolated case reports include: (1) over 250,000 turkeys lost in a 3-year period in North Carolina, (2) almost half of a 1,000-egg-laying flock of hens lost, with egg production of the survivors reduced by 5 percent, (3) about 60 percent of a swine herd lost during a 3-week period, (4) loss of 25 to 100 steers daily for 2 weeks in a Midwestern feedlot before the cause was found, and (5) an increase of about 15 percent in the feed/gain ratio, a 1/4-pound reduction in final weight, a doubling of mortality, and a tripling of processing-line condemnations in an integrated broiler operation (8). It is likely that much loss is in the form of lower production rates and therefore goes unnoticed.

Mold loss can be avoided in storage by taking proper precautions. However, these precautions have their cost. Some preservation measures are taken on most corn going into storage. Otherwise, storage loss would be much higher. Still, some farmers choose to risk loss rather than pay the cost for preservation, as represented by the 250 million bushels of annual corn spoilage.

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2/ Underscored numbers in parenthesis refer to reference items at the end of the report.

Table 1--Methods of harvesting, handling, and drying corn for storage in 3 Corn Belt States, 1964-71

Item	State	1964	1965	1966	1967	1968	1969	1970	1971
		Percent							
Acreage harvested with: 1/									
1. Mechanical picker	Iowa	81	75	66	60	57	51	46	42
Do	Ill.	55	46	43	36	35	30	24	23
Do	Ind.	47	44	34	29	32	29	23	23
2. Field picker-sheller	Iowa	6	6	7	8	8	8	8	8
Do	Ill.	7	9	9	8	8	8	8	8
Do	Ind.	7	8	7	9	8	9	7	8
3. Corn head on combine	Iowa	13	19	27	32	35	41	46	50
Do	Ill.	38	45	48	56	57	62	68	69
Do	Ind.	45	48	59	62	59	62	69	68
Methods of handling at harvest:									
1. Marketed from field	Iowa	9	7	9	7	11	13	13	10
Do	Ill.	24	25	18	17	16	20	21	19
Do	Ind.	24	32	31	32	28	31	29	26
2. Stored on farms	Iowa	90	90	84	83	82	79	79	78
Do	Ill.	72	69	71	69	73	68	65	62
Do	Ind.	70	59	58	55	62	59	59	59
3. Stored by producer off farm	Iowa	1	3	7	10	7	8	8	12
Do	Ill.	4	6	11	14	11	12	14	19
Do	Ind.	6	9	11	13	10	10	12	15

Continued

Table 1--Methods of harvesting, handling, and drying corn for storage in 3 Corn Belt States, 1964-71--Continued

Item	State	1964	1965	1966	1967	1968	1969	1970	1971
		Percent							
Methods of drying corn stored on farms:									
1. Naturally	Iowa	86	83	78	69	68	62	57	55
Do	Ill.	79	70	61	48	48	48	34	39
Do	Ind.	63	67	51	41	46	41	37	31
2. Artificially on farm	Iowa	13	16	21	28	27	35	41	43
Do	Ill.	21	30	37	50	50	51	65	60
Do	Ind.	36	33	48	57	53	57	62	65
3. Artificially off farm	Iowa	1	1	1	3	5	3	2	2
Do	Ill.	0	0	2	2	2	1	1	1
Do	Ind.	1	0	1	2	1	2	1	4

1/ When figures for an individual State do not round to 100 percent, the "other" method category (not given in this table) exceeded 0.5 percent.

Source: Statistical Reporting Service, Corn for Grain: Harvesting, Handling and Drying Methods, U.S. Dept. Agr.

Reducing moisture content has been the major method of preserving stored grain. Moisture content below 13 percent is considered safe from mold invasion (3). This method has evolved from natural field drying to various artificial drying procedures that remove moisture after the grain is harvested. In Illinois, over 60 percent of on-farm stored corn was dried artificially in 1970 and 1971, compared with 21 percent in 1964 (table 1). Drying procedures have encouraged earlier harvest (before the corn is field dried) to avoid field loss from weather hazards.

Farmers in the last decade or so have tried various ways of moisturizing feed grains before feeding. Since higher moisture grain is favored for feeding (12), methods that prevent mold growth in stored grain of more than 13 percent moisture would be an asset if economically feasible. Reduced oxygen content of the storage atmosphere, low-temperature storage, and application of sorbic acid and K sorbate (in combination with continuous flushing with carbon dioxide atmospheres) have been tested (5). Two acids recently were put on the market for commercial use. One is propionic acid, and the other is a propionic and acetic acid mixture. Effective measures used so far have added 10 to 20 percent in cost to the farm price of grain. If used as recommended, the treatments do preserve the grain against mold spoilage. The quality of the grain, however, may decrease to some extent during the storage period.

New Storage Treatments

Recent pressures on energy supplies give added incentive to find ways of preserving grain other than by drying. Chemical treatment may be used alone or combined with drying to reduce the drain on scarce energy sources. With the increasing national concern over scarce energy, the economics of corn preservation may change rapidly during the next decade.

New methods of treating grain for storage are being investigated by scientists in the Agricultural Research Service of the U.S. Department of Agriculture. Ammonia treatment is one method which has received attention (1). Laboratory studies show that ammonia is a good fungicide and that its preservative effects last over a period of several months under favorable storage conditions. Field studies indicate that the inhibitory effect of the chemical preservatives do diminish, so that micro-organisms can reenter stored corn. In a pilot treatment with ammonia, chemical heating destroyed the ammonia's protective capability more rapidly than in laboratory tests. However, the organisms in the pilot test were not those producing toxic substances.

Not only does ammonia treatment of corn control microbial growth, but it also is of economic interest to animal nutritionists as a source of nonprotein nitrogen. Ammonia contains about twice as much nitrogen as urea and many times that of soybean meal. The nitrogen content of corn can be increased by ammoniation to near a complete ration for ruminants at much less cost than by adding a protein supplement, and at considerably less cost than by supplementing with urea. Means of holding down production costs of beef and other dairy products become more attractive as protein supplements increase in price. Feeding trials of ammoniated corn, however, are not yet conclusive.

Preliminary experiments used aqua ammonia because applying it at a uniform rate is easier than applying anhydrous ammonia (11). This study was conducted to evaluate the economic potential of aqua ammonia as a high-moisture stored corn preservative in a local demand-supply situation. It is limited primarily to corn stored on farms because current technical investigations mainly concern corn used as feed. Because of discoloration and possible flavor effects, it is unlikely millers would readily accept ammoniated grain even if aqua ammonia treatment should prove to be technically successful. Consequently, if aqua ammonia were proved to be an effective preservative, it would probably have to make its economic entry into commercial use in the Corn Belt for corn stored on farms for feed. However, there is no evidence other than the color and

flavor problems that is contrary to the potential of treating grains in commercial storage or even grains destined for food.

This study considers the potential market for aqua ammonia as a stored corn preservative in onfarm units and, particularly, in a local setting. Supply conditions and costs are outlined and discussed. Preservation alternatives that were evaluated and compared with aqua ammonia treatment are artificial drying and the new acid treatments. Also, some aspects other than cost that will affect ammonia's potential competitiveness are discussed.

POTENTIAL DEMAND

Marketing Area

The size of the potential market for aqua ammonia treatment is unknown. Although predicting its size is subject to error, a starting point is the total stocks of stored grains (table 2).

The 1968-70 peak quarter storage stocks of the different grains indicate grain storage amounts of nearly 250 million tons annually. About 74 percent of total stored stocks was feed grains, and 26 percent was food grains. Sixty-three percent of all stored grains was in onfarm storage facilities. Seventy-one percent of the peak feed grain stocks was stored on farms, compared with only 39 percent of the food grains.

Stocks of stored grain ultimately will determine the size of the aqua ammonia market if it is commercialized as a stored grain preservative. However, which grains and what part of their stocks will be treated is not known.

To treat all stored grains with a 0.5-percent application of NH_3 (ammonia) would require over 4 million tons of aqua ammonia annually. To treat only the feed grains would require more than 3 million tons, and to treat only feed grains in farm storage would require over 2 million tons. The last figure probably represents the upper limit of the initial potential market. If aqua ammonia proves successful as a preservative, it could, in time, penetrate the off-farm stored feed grain markets and, possibly, even stored food grain markets.

Currently, discussion by most scientists working in the area of acid preservatives tends to rule out treatment of grains used for food. The reason, apparently, stems from recognized difficulties in getting acceptance of such treatment for feed grains due to discoloration and flavor problems and to a lack of chemical knowledge necessary to gain FDA clearance.

One concern about the potential market for aqua ammonia as a preservative is whether quantities used locally would be sufficient to support a local supply. A local supply involves the investment in and operation of a convertor unit to mix anhydrous ammonia with water to form aqua ammonia.

Experience in handling aqua ammonia as a fertilizer apparently gave rise to the belief that its long-distance transportation is unfeasible. At one time, considerable quantities of aqua ammonia were used as fertilizer and supplied locally to farmers. However, with improvements in handling equipment and procedures for storage, delivery, and application, anhydrous ammonia began replacing aqua ammonia in fertilizer use. Local supply firms are prone to attribute the decline in use of aqua ammonia to the necessity for handling and transporting four times the weight of anhydrous ammonia to supply an equal amount of nitrogen fertilizer. This argument is sound. However, transportation of aqua ammonia only became unfeasible after anhydrous ammonia became acceptable as an alternative.

Table 2 --Average annual storage stocks of grain by quarter, type of grain, and storage location, 1968-70

Grain	Date of peak stocks	Average annual stocks: On farm	Average annual stocks: Off farm	Total	Annual rate of increase 1/
		1,000 tons			Percent
Wheat	Oct. 1	21,436	31,966	53,402	-2.1
Rye	Oct. 1	459	635	1,094	1.8
Rice (rough only)	Jan. 1	576	2,561	3,137	2/
Total food grains		22,472	35,162	57,633	3/ -2.0
Corn	Jan. 1	93,646	26,293	119,939	0.6
Oats	Oct. 1	13,322	3,172	16,494	-1.0
Barley	Oct. 1	7,402	4,206	11,608	0.0
Sorghum	Jan. 1	5,743	14,431	20,174	0.3
Total feed grains		120,113	48,102	168,215	0.3
All grains		142,585	83,264	205,675	3/ -0.3

1/ From 1958-60 to 1968-70.
2/ Not available for earlier years.
3/ Excluding rice.

Source: Economic Research Service, Food Grain Statistics, Supplement for 1971 to Statistical Bulletin No. 423, U.S. Dept. Agr., Nov. 1972. Economic Research Service, Feed Statistics Supplement for 1971 to Statistical Bulletin No. 410, U.S. Dept. Agr., July 1972.

As a stored grain preservative, it is unlikely that, initially, anhydrous ammonia would be an alternative for aqua ammonia, due to problems in getting uniform application at the low levels desired. Consequently, transportation costs of water in aqua ammonia are not measured over and above or relative to the cost of supplying anhydrous ammonia. Water in this situation is merely a necessary ingredient of the treatment material, and transportation is a variable in alternative supply locations. If a means of successfully treating with anhydrous ammonia is later found, then the cost of transporting the water in the aqua form of ammonia takes on significance.

It is possible that some firms may find it economical to convert anhydrous ammonia at larger, centrally located plants and transport it to local supply points. Cost gains in converting larger quantities may more than compensate for transportation costs. However, since the question of transportation costs does exist, this report focuses on local supply and demand.

The potential size of the local market is estimated in terms of onfarm storage of corn by counties in Illinois in 1970 and 1971. The State's production of corn in 1971 was 40 percent greater than in 1970, when corn leaf blight severely reduced the crop. All the State's crop-reporting districts, as well as most counties within each district, had higher production in 1971. Thus, a relatively poor crop and a relatively good crop are represented in the two annual figures.

County production figures varied from 150,000 to 29,600,000 bushels in 1970. Only eight counties produced less than 1 million bushels. In 1971, production varied from 236,000 to 42,247,000 bushels, with only seven counties producing less than 1 million bushels.

County figures for corn stored in farm units were estimated by applying the district percentage of production in 1970 and 1971 in onfarm storage on January 1 (1971 and 1972, respectively) to the county production figures. The proportion of corn stored on farms is higher than for most other grains due to the large amount of combined corn-livestock operations in the Corn Belt. January 1 onfarm storage stock was about 54 percent of the previous crop harvested in both 1970 and 1971 for the State (table 3). It varied from slightly less than 50 percent to over 60 percent.

Estimates of county onfarm storage of corn in Illinois for the 1970 crop ranged from 76,000 to over 14 million bushels, and for the 1971 crop, from 110,000 to almost 21 million bushels. About 23 percent of the counties had less than 1 million bushels of the 1970 crop stored onfarm, compared with only 9 percent for the 1971 crop. The proportion of counties having 1 to 6 million bushels of corn in onfarm storage was 56 percent for the 1970 crop and 54 percent for the 1971 crop. About 37 percent of the counties had more than 6 million bushels of the 1971 crop stored onfarm, compared with only 22 percent for the 1970 crop.

It was not known what proportion of the grain stored in onfarm units might be later sold into commercial channels rather than fed on the farm. Nor was it known whether the grain that was sold was destined for food or feed use. However, the proportion stored for later feed use is very high in many counties in Illinois.

The estimated amounts of corn stored in onfarm storage by counties was used to estimate the potential county markets for aqua ammonia in Illinois. It was assumed that 1 ton of aqua ammonia would treat 1,700 bushels of 25-percent moisture corn (a 0.65-percent level dry weight basis with no loss of NH_3). Figures 1 and 2 show the demand situation by counties for the 1970 and 1971 corn crops, respectively. Those counties with relatively light demand potential tend to be concentrated in the lower parts of the State, excluding the Chicago area.

Table 3 --Corn production and storage, by districts in Illinois, 1970 and 1971 crops 1/

District	Production		Farm storage stocks January 1		Storage stocks/production	
	1970	1971	1971	1972	1970	1971
	1,000 bushels				Percent	
Northwest	130,844	175,425	83,283	109,234	64	62
Northeast	81,655	111,706	51,644	69,852	63	63
West	76,648	107,662	43,317	63,080	56	59
Central	122,864	179,338	58,834	81,361	48	45
East	122,455	167,372	58,930	83,412	48	50
West Southwest	82,812	120,312	40,416	63,057	49	52
Southeast	19,732	31,178	10,001	14,470	51	46
East Southeast	79,235	115,537	39,717	57,739	50	50
Southwest	19,316	28,810	11,060	17,959	57	62
Illinois	735,560	1,037,340	397,202	560,164	54	54

1/ Illinois Cooperative Crop Reporting Service, Illinois Agricultural Statistics: Annual Summary, 1972, Bulletin 72-1, and Crops, Jan. 28, Oct. 1, and Nov. 1, 1972.

POTENTIAL DEMAND FOR AQUA AMMONIA AS AN ONFARM STORED CORN PRESERVATIVE

1970 CROP

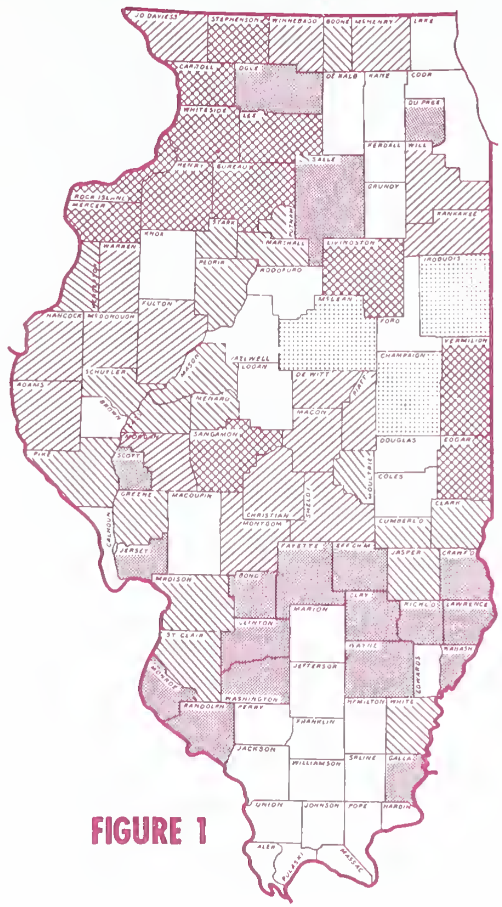

FIGURE 1

1971 CROP

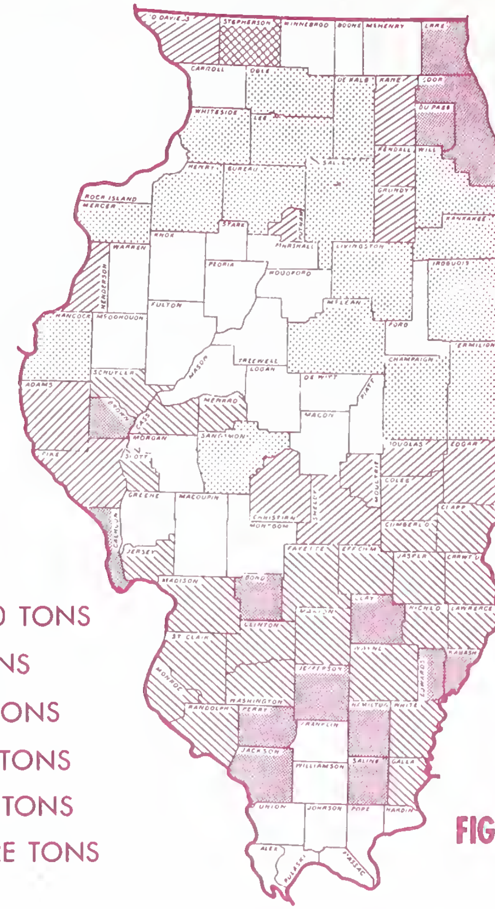

FIGURE 2

- LESS THAN 500 TONS
- 500 — 999 TONS
- 1,000 — 1,999 TONS
- 2,000 — 3,999 TONS
- 4,000 — 5,999 TONS
- 6,000 OR MORE TONS

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Only 20 percent of the Illinois counties in 1970 and 9 percent in 1971 had corn in onfarm storage that represented a potential demand of less than 500 tons (table 4). Forty percent of the counties in 1970 and 23 percent in 1971 had a potential demand of less than 1,000 tons. A farm supply service could probably maintain a profitable convertor operation based on supplying as few as 500 tons of aqua ammonia per season. And, 1,000 or more tons per season would certainly support profitable convertor operations.

Table 4 --Potential demand estimates for aqua ammonia as a corn preservative, by counties in specified categories, 1970 and 1971 crops 1/

Range in tons of aqua ammonia	Number of counties		Accumulative percentage of counties	
	1970	1971	1970	1971
	Number		Percent	
Less than 500...........	20	9	20	9
500-999.................	20	14	39	23
1,000-1,999.............	19	23	58	45
2,000-3,999.............	30	26	87	71
4,000-5,999.............	10	16	97	86
6,000 and above.........	3	14	100.0	100.0

1/ Based on estimates of total corn in onfarm storage on January 1 following harvest. County estimates were computed by multiplying county production by the proportion of district production in onfarm storage on January 1. County corn in onfarm storage figures were divided by 1,700 (assumed bushels that 1 ton of aqua ammonia would treat) to compute demand estimates. This latter figure is based on a 24.3 NH_3 solution with an application rate of 0.65 dry weight basis.

Supply Conditions

There are technical difficulties in using anhydrous ammonia as a preservative. Its reaction to the presence of water, the difficulty in getting uniform application, the difficulty in getting a sufficiently low rate of application, and its volatile nature present problems in application. Aqua ammonia, on the other hand, can be directly applied with a metered applicator, similar to the type used in applying propionic acid, attached to a conveyor belt that moves corn into a farm storage unit. Consequently, testing has been with aqua ammonia, and commercialization initially would probably be with the aqua form. Should ammoniation of grain in storage prove technically successful and economically feasible, efforts would probably be made to devise ways to apply the anhydrous form (11).

Ammonia is a relatively inexpensive chemical. The aqua solution, however, carries about 3 pounds of water to 1 pound of NH_3 and is considered to be costly to transport. Consequently, a supply station where anhydrous ammonia is converted to aqua ammonia fairly near the area of use may be the most economically feasible method of supply.

Since aqua ammonia has been supplied as a fertilizer, supplying it as a preservative would have built-in economic advantages. The advantages are: (1) available

capital equipment, (2) accumulated experience in aqua ammonia supply to farmers, and (3) investors anxious to find alternative uses for convertor equipment as aqua ammonia declines in use as a fertilizer.

Convertors that produce aqua ammonia from anhydrous ammonia are widely scattered throughout Illinois and the Midwest. They were in high demand in the mid-1960's when use of aqua ammonia as a fertilizer was at its peak. However, the increasing use of anhydrous ammonia as a fertilizer has threatened obsolescence to many or all the local convertor plants. Many of the more than 100 convertor units within Illinois are idle.

Convertor models in local use range in rated capacity from about 10 to 40 tons per hour. The smallest (10 tons per hour) is capable of converting 10,000 gallons (26 tons or one tank car) of anhydrous ammonia into about 106 tons of aqua ammonia in approximately 10 hours of operation. The next largest convertor (representing approximately half the local plants in Illinois) is rated at twice that capacity. Apparently, nearly three-fourths as much time is required to convert a tank car with the larger model than with the smaller one. The smaller convertors are adequate for providing a local supply of aqua ammonia. Also, they may have greater economic feasibility than larger models operated at central locations which would require greater transportation of aqua ammonia.

The question here is whether the potential local demand is sufficient to justify costs of operating the smaller convertor units. The period of supply is crucial aince ordinarily the bulk of the demand would be during the 3 to 4 weeks of harvest. During that period, the smallest unit probably could be relied on to provide a maximum of 4,000 to 5,000 tons of aqua ammonia if on a 24-hour schedule of operation. Probably 2,000 to 3,000 tons would more nearly represent its normal seasonal supply capability. Thus, it would appear that the smaller units are sufficient to supply the potential demand by counties of one-third to one-half of Illinois.[3/] One-half to two-thirds of the State may need additional smaller units or a larger unit to adequately care for the harvest needs.

Production Costs

Estimates of maximum supply costs of aqua ammonia are provided in this section. The smallest convertor in general use is the only model considered. It is capable of producing about 100 tons of aqua ammonia per one-shift day, representing potential treatment of over 187,000 bushels of corn at the 0.5-percent level of application. The capacity could be doubled by running at night. Larger models probably would be purchased only if demand were sufficient to take their output, thereby resulting in a lower cost per ton of aqua ammonia produced than with the smaller convertors.

Table 5 shows investment cost estimates along with the relevant assumptions. These estimates include costs for the convertor itself, two aqua ammonia storage tanks, an anhydrous ammonia storage tank, four "nurse" tanks to use for farm delivery, and the necessary hardware, transportation, labor, and other costs in establishing the plant and readying it for operation. These estimates are liberal. For example, it may not be necessary for some firms to have an anhydrous ammonia storage tank, for farm delivery tanks may be filled directly from the rail car.

3/ Some consolidation of counties to provide sufficient demand for economic operation of the small units would be necessary. It is unlikely that consolidation, which may result in transporting aqua ammonia to delivery points 30 to 40 miles from the plant, would seriously affect costs and, consequently, supply.

Table 5 --Investment cost estimates for a small commercial convertor of anhydrous ammonia 1/

Item	Total cost
	Dollars
Convertor: Unit cost 2/	7,700
Two 19,000-gallon aqua tanks with loadout pump 2/	4,900
Remaining plant cost: Hardware, transportation, setting up, and other expenses 2/	8,050
Anhydrous ammonia storage tank 3/	14,000
Four aqua ammonia "nurse" tanks for delivery 4/	4,000
Total investment	38,650
Annual depreciation 5/	2,061
Annual interest cost 6/	1,649
Annual repairs 7/	700
Total annual fixed cost	4,410

1/ Costs do not include office and management overhead. Rated capacity to convert a 10,000-gallon (approximately 26 tons) rail tank car of anhydrous ammonia per day, producing approximately 10 tons of aqua ammonia per hour (106 tons per day).

2/ Estimated cost in factory brochure. Generally, local farm supply firms labeled the costs "about right" or "too high."

3/ 20,000-gallon tank or larger, capable of storing two rail tank cars of anhydrous ammonia.

4/ 1,000-gallon capacity each at estimated cost of $1,000 each which includes transfer pump.

5/ A 15-year life on the convertor and 20-year life on all other investment items assumed.

6/ Interest cost was amortized at a 7-percent rate for 15 years on the convertor and for 20 years on other equipment.

7/ Estimated. Most of the equipment needs minimum maintenance such as occasional cleaning and painting. The convertor's main requirement, apparently, is replacement of the cooling coil in 5 to 8 years. Estimates of annual average repairs for the convertor ranged from $200 to about $500. From data at hand, it appears an annual repair of $400 for the convertor and $300 for other equipment is a liberal estimate.

The estimated investment cost for activating an aqua ammonia plant is $38,650. With interest rates, depreciation rates, and repair conditions as given, annual fixed cost amounts to $4,410. About 47 percent is depreciation, 37 percent is interest on investment, and 16 percent is an average annual repair cost.

Data in table 6 provide estimates of the plant's annual overhead, operation, and supply cost--divided into their respective components. The raw material (anhydrous ammonia) represents 62 to 82 percent of total cost, although, as explained in a

Table 6 --Annual operating cost estimates per ton of aqua ammonia produced with a small commercial convertor plant

Cost item	Operating cost per ton with specified annual production in tons 1/ 500	1,000	2,000	4,000
	Dollars per ton			
Overhead:				
Depreciation	4.12	2.06	1.03	.52
Interest	3.30	1.65	.82	.41
Annual repairs	1.40	.70	.35	.18
Office and management overhead	.88	.44	.22	.11
Total overhead	9.70	4.85	2.42	1.22
Operating:				
Electricity 2/	.035	.035	.035	.035
Water:				
For mixing 3/	.085	.085	.085	.085
For cooling 4/	.070	.070	.070	.070
Labor at plant 5/	.25	.25	.25	.25
Anhydrous ammonia 6/	18.75	18.75	18.75	18.75
Delivery 7/	1.50	1.50	1.50	1.50
Total operating cost	20.69	20.69	20.69	20.69
Total supply cost	30.39	25.54	23.11	21.91

1/ Producing 100 tons of aqua ammonia per one-shift day would require 5 to 40 days of operation. Peak harvest-season requirements could be met by running nights.

2/ Based on the plant's electrical-connected horsepower of 13-1/3, an electricity price rate of 3.0 to 3.4 cents per kilowatt-hour and a production rate of 10 tons of aqua ammonia per hour.

3/ 1,514 pounds of H_2O per ton of aqua ammonia equals 24.3 cubic feet (1 cubic foot of water weighs 62.3 lbs.). Water rates vary by municipality and generally by quantity used per month. Rate assumed here is 35 cents per 100 cubic feet.

4/ Assumes an average of 1,500 gallons per hour or 150 gallons per ton of aqua ammonia produced.

5/ Assumes a wage of $2.50 per hour, production of 10 tons per hour, and a labor force of one man full time while operating.

6/ Assumes anhydrous ammonia at $75.00 per ton. This cost is the selling price by farm supply firms rather than acquisition cost. It is used as a built-in profit factor in the final supply cost of aqua ammonia.

7/ Assumes that one man delivers 25 tons per day with average mileage on a 4-ton delivery of 20 miles at a pickup allowance of 14 cents per mile--80 cents labor costs per ton and 70 cents truck costs per ton.

footnote in table 6, this has a profit element embodied in it. Overhead varies from 6 to 32 percent, depending on seasonal production. Operation costs (other than for raw material) are only 6 to 9 percent of total supply costs.

The data need to be clarified in several respects. The overhead costs, including investment costs, are "fixed" because the components are the same regardless of volume produced. However, these costs do vary per unit of product because they are spread

over larger quantities as production increases. Computation of overhead costs per ton assumes no time limitations from the demand side. To produce 4,000 tons would require approximately 40 days of one-shift operation. (A limited corn harvest time makes it unlikely that a small plant could supply more than 4,000 tons per season.) If peak-season needs required more than a daily one-shift capacity, the plant could also be run at night. Night operation might conceivably require higher wages or more labor per shift to operate, which would result in somewhat higher costs. On the other hand, the cooler atmosphere at night would have offsetting advantages, such as greater production and less water needed for cooling, for temperature is a critical factor in the conversion process.

Supply costs are not likely to go above $30 per ton at the 500-ton level (table 6). If a plant were operated at less than a 500-ton seasonal output, overhead costs would be higher. However, some plant managers believe that if their service area drops below a 1,000-ton requirement it would become economically feasible to enlarge the service area to gain sales volume.

The $18.75 raw material cost was based on the price farmers pay for anhydrous ammonia. The farmers are presently being supplied anhydrous ammonia for use as fertilizer by local farm supply firms at costs ranging from $70 to $80. Few firms, however, quote prices above $75 per ton. It is that price that the supply firm depends on to pay expenses and make a profit. The firm's selling price of anhydrous ammonia, rather than its acquisition price (which is the one relevant as a cost item), was used because the profit imbedded in it is considered a buffer margin to make the total supply cost shown in table 6 a liberal estimate.

The supply price of aqua ammonia to farmers, under present cost conditions, for use as a stored corn preservative is not likely to exceed $30 per ton. Competition in many areas would probably set it at almost $25 per ton. The estimated supply price for a small convertor plant operating at a maximum 4,000-ton output is only $22 per ton.

Competitive Potential

Table 7 compares costs of potential aqua ammonia treatment with costs of other preservation treatments of stored corn. Generally, corn is not harvested with a moisture content over 30 percent. However, occasionally it is, and harvesting at higher moisture levels may occur more often with widespread adoption of treatments that maintain the quality of high-moisture grain in storage.

Ortho-Guard costs are based on those given in the company brochure. Local supply firms that handle the chemical indicated that those costs are reliable. One cent per bushel was added to the chemical cost to cover the cost of application at the farm.

Treatment with Ortho-Guard costs the farmer almost 9 cents to more than 15 cents per bushel. Application of ChemStar apparently runs a bit higher. These new chemical treatments probably cost somewhat more than conventional onfarm drying, but farmers find their greater convenience in use appealing.

Total cost of artificial drying (table 7) ranged from 1 cent per percentage point of moisture removed per bushel when corn was harvested at the lower moisture content level to about 0.65 cents per percentage point when corn was harvested at the higher moisture level. These figures are moderate, being lower than some estimates and higher than others. Data indicate that drying can compete very well with the new chemicals if cost alone is considered. If those chemicals replace drying, the replacement will come as a result of a lowered price level or of advantages over drying in other respects.

Table 7 --Comparative cost estimates for alternative preservation treatments of stored corn, at specified moisture levels

Treatment	Moisture content at harvest		
	20-25%	25-30%	30-35%
		Cents per bushel	
Ortho-Guard 1/	9 - 13	12 - 16	14 - 17
ChemStar 2/	12 - 14	16 - 19	18 - 21
Drying 3/	6.5 - 8.5	9.0 - 11.0	11.5 - 13.0
Aqua ammonia 4/	2.3 - 2.6	2.6 - 3.0	3.0 - 3.5

1/ Based on application recommendations in the manufacturer's brochure, their suggested chemical cost of 29 cents per pound or 1.8 cents per ounce, and an assumed cost of 1 cent per bushel for the applicator and labor. The applicator's annual cost ranges from .75 cent to 1.5 cents per bushel when handling 15,000 to 7,500 bushels, respectively, assuming $710 initial costs, $71 annual depreciation cost (10-year life), 7-percent amortized interest cost, and 2 percent of initial investment as annual repair allowance. Labor for application amounts to 0.3 cents per bushel at a wage of $2.50 per hour and a 900-bushels per hour rate of handling. However, most of this labor cost is merely for putting grain in storage which would be necessary even if the grain was not treated.

2/ Based on cost and application rate advertised by the manufacturer at the 25-percent moisture content level in the Prairie Farmer; Sept. 16, 1972. Variation by moisture content levels assumed the same as for Ortho-Guard. The range of both chemical costs in each moisture content category represents variation due to storage time and moisture level.

3/ Cost of drying varies considerably among farmers as revealed by published studies. Costs used here were about 1 cent per percentage point of moisture removed per bushel of grain harvested at 20-25% moisture, about 0.8 cent per percentage point per bushel when harvested at 25-30% moisture, and about 0.65 cent per percentage point per bushel when harvested at 30-35% moisture.

4/ Variations due to assuming supply price from $22 to $30 (see table 6) and somewhat higher application levels (from 0.5% to 0.7% by weight) at higher moisture contents. The cost includes 1 cent per bushel for farm application cost.

There is little doubt that, given the current alternatives, aqua ammonia preservation would be a preferred treatment costwise. Quoted carlot wholesale prices in trade journals suggest that the new chemical treatments may have a potential of being supplied at lower prices, not likely to exceed 25 percent less than the present supply price. Even with this potential reduction, these treatments are unlikely to compete with the costs estimated for aqua ammonia.

The supply cost of $30 per ton at the 500-ton output is considered a reasonable (and liberal) maximum. Many firms operating the small units would have higher annual volumes than allowed for in estimating the cost. Also, many firms would have sufficient demand to operate larger convertors, thus lowering costs below those computed for this study. Therefore, it appears that the price most likely to prevail for aqua ammonia would be approximately $25 per ton.

CONCLUSION

Factors other than cost have received little attention in this report. Some of these factors represent unknowns in aqua ammonia treatment as a preservative, and in other acid treatments for that matter. The study assumes that aqua ammonia would prove technically to be an effective preservative.

Tests of aqua ammonia as a preservative so far have been encouraging. Still, there are many unanswered questions. The chemical reaction of ammonia with corn constituents, particularly, the reaction which results in "browning" needs multidiciplinary research attention. Quantification of caloric loss during heating, modification of amino acids in grain and their effect in feeding, rates of fixation and storage life, and odor and color problems are only a few areas that need laboratory attention.

Chemical treatments may require better storage bins than are necessary for dried grain. However, the stirring and care to prevent moisture regain that is necessary for dried grain in storage may be eliminated for chemically treated grain.

Chemically treated grain is believed to have a higher feed value than dried grain. It may be less palatable, although its higher moisture content may be an offsetting factor in palatability. Aqua ammonia has the potential of adding a significant amount of nonprotein nitrogen to the grain. Feeding trials with ammoniated corn, however, are not yet conclusive.

Apparently, there are many more questions than answers concerning preservation of high-moisture corn in storage. In terms of cost and conditions of supply, aqua ammonia has considerable competitive potential if it proves to be technically effective. Using cost data in table 7 as a base, it appears that 5 cents per bushel is a reasonable expectation of average savings with aqua ammonia use. That savings applied only to corn in onfarm storage would mean \$150 million to \$175 million in savings annually.

What do these figures mean? They say in effect that the potential reward seems to justify research effort to resolve these unknowns in using aqua ammonia as a preservative.

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